

## Comment on "Viable singularity-free $f(R)$ gravity without a cosmological constant"

A modified  $f(R)$  gravity model has been recently proposed in [1] whose cosmological behaviour is clearly distinguishable from  $\Lambda$ CDM. Contrary to previous opinions which consider that self-consistent  $f(R)$  gravity models distinct from  $\Lambda$ CDM are almost ruled out, the authors claim that the proposed model is cosmologically viable. Here we show that although the model satisfies some consistency conditions, precisely because of its departure from  $\Lambda$ CDM behaviour, it does not satisfy local gravity constraints and, in addition, the predicted matter power spectrum conflicts with SDSS data.

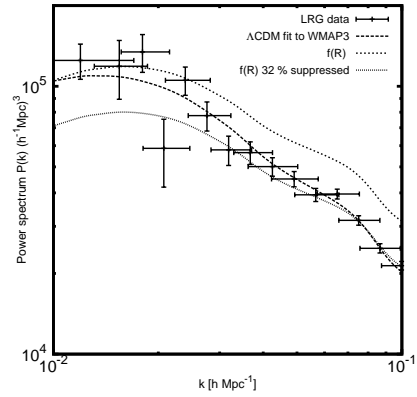
Out of the four viability conditions imposed on  $f(R)$  theories [2], the proposed model satisfies three of them. The fourth condition, namely,  $|f_R - 1| \ll 1$  at recent epochs, is imposed by local gravity tests. Although it is still not clear what is the actual limit on this parameter, certain estimates [3] give  $|f_R - 1| < 10^{-6}$  today, [4]. This condition also ensures that the cosmological evolution at late times resembles that of  $\Lambda$ CDM. However, in the proposed model,  $|f_R - 1| \sim 0.2$  today for  $\alpha = 2$  and  $q_0 \sim -0.25$ . In principle, if we are only interested in large scales, we could ignore local gravity inconsistencies, but still the deviations from  $\Lambda$ CDM can have drastic cosmological consequences on the evolution of density perturbations, as discussed by several authors [5, 6, 7].

Thus, the linear evolution of matter density perturbations for sub-Hubble ( $k\eta \gg 1$ ) modes in  $\Lambda$ CDM is given

by the well-known expression:

$$\delta'' + \mathcal{H}\delta' - 4\pi G\rho_0 a^2 \delta = 0 \quad (1)$$

where  $\delta = \delta\rho/\rho_0$ ,  $\mathcal{H} = a'/a$  and prime denotes derivative with respect to conformal time  $\eta$ . Notice that the evolution of the Fourier modes does not depend on  $k$ . This means that once the density contrast starts growing after matter-radiation equality, the mode evolution only changes the overall normalization of the matter power-spectrum  $P(k)$ , but not its shape. However in  $f(R)$  the-



**Figure 1:** Linear matter power-spectra for  $\Lambda$ CDM and  $f(R)$  in [1] with  $\alpha = 2$ . Data from SDSS [8].

ories, the corresponding equation reads [7]:

$$\delta'' + \mathcal{H}\delta' + \frac{f_R^5 \mathcal{H}^2 (-1 + \kappa_1)(2\kappa_1 - \kappa_2) - \frac{16}{a^8} f_{RR}^4 (\kappa_2 - 2) k^8 8\pi G\rho_0 a^2}{f_R^5 (-1 + \kappa_1) + \frac{24}{a^8} f_{RR}^4 f_R (\kappa_2 - 2) k^8} \delta = 0 \quad (2)$$

where  $\kappa_1 = \mathcal{H}'/\mathcal{H}^2$  and  $\kappa_2 = \mathcal{H}''/\mathcal{H}^3$ . Notice the  $k^8$  dependence in the last term which appears due to the fact that  $f_{RR} \neq 0$ . This means that the matter power-spectrum is further processed after equality and the transfer function is modified with respect to that of  $\Lambda$ CDM. This drastically changes the shape of  $P(k)$ , as shown in Fig. 1, where normalization to WMAP3 has been imposed. In the figure, SDSS data from luminous red galaxies [8] and the  $\Lambda$ CDM power spectrum from the linear perturbation theory with WMAP3 cosmolog-

ical data are also shown. Notice that  $\Lambda$ CDM gives an excellent fit to data with  $\chi^2 = 11.2$ , whereas for the  $f(R)$  theory  $\chi^2 = 178.9$ , i.e.  $13\sigma$  out. Even if we drastically reduced the overall normalization in a 20%, the discrepancy would still remain at the  $7\sigma$  level. Actually, the best fit would require a 32% normalization reduction and still would be  $4.8\sigma$  away (see Fig. 1).

A. de la Cruz Dombriz, A. Dobado and A.L. Maroto.  
Dept. Física Teórica I, Universidad Complutense de Madrid, 28040 Madrid, Spain.

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